10/576888
IAP20 Rec'd PCT/PTO 24 APR 2006

The Examiner had rejected claims 1 to 4 for failure to comply with Article 33(3) of the Patent Cooperation Treaty, and asserted that claims 1 to 4 were obvious to the person skilled in the art in view of U.S. Patents 5,121,456; 5,307,431; 6,357,933 and 5,768,455 and in view of JP patent application 2002-311293 and European patent application 1,148,366. The Applicant respectfully traverses the Examiner's rejection on the aforesaid basis.

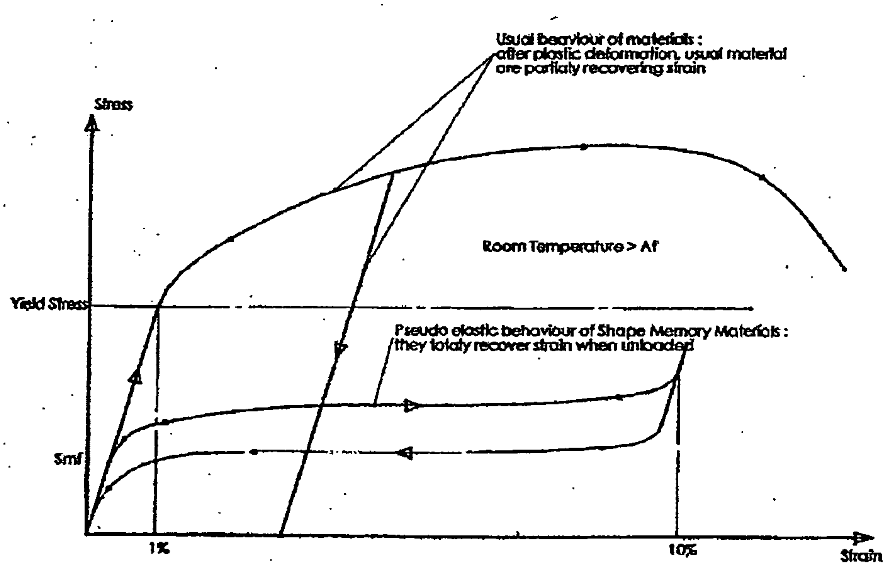
The Examiner had cited US patent 5,121,456 (hereinafter D1) against claims 1 to 4 allegedly on the ground that they were rendered obvious by this reference.

The Examiner asserted that D1 is considered to be the most relevant prior art reference cited against the present application. In essence, the Examiner asserted that D1 is directed to a device for mechanically connecting optical fibers and a tool to introduce and remove optical fibers from the device. D1 is directed to a splicer that is made of as least four parts: which has first and second mirror image body halves and first and second outside body halves each of which having a recess for receiving the splice element. The Applicant respectfully submits that the subject matter of the present application is completely different from D1 considering that the tool of the present application is made of only one part. Furthermore, in the present application, independent parts do not need to be fused to make the ferrule of the present application. The reason that the ferrule of the present application does not need to be fused results from the fact that the ferrule is made from Shape Memory Materials. D1 cited by the Examiner does not teach the use of Shape Memory Materials to deform and reform the ferrule. Shape Memory Materials exhibit two very unique properties, which are pseudo-elasticity and the shape memory effect. These two unique properties are made possible through a solid-state phase change, that is a molecular rearrangement, which occurs in the shape memory material. The two phases that occur in shape memory materials are Martensite and Austensite. Martensite, is the relatively soft and easily deformed phase of shape memory materials, which exists at lower temperatures. Austensite, the stronger phase of shape memory materials occur at higher temperatures. The temperatures at which each of these phases begin and finish forming are represented by the following variables: Ms, Mf, As, Af.

Shape memory materials (SMM) are characterized by the following behavior: when the material is below a temperature (Mf), which is a property dependent on the particular SMM, it is possible to strain (deform) the material. The strain is quite easily obtained by stressing the material with a relatively low stress. When the stress is released, the SMM retains the greatest part of the strain. When the SMM is heated above a second temperature (Af), which is also dependent on the particular SMM, the SMM will recover

the strain. The recovery of the strain is total unless the stress used to deform the SMM exceeds the yield strength of the material. Thus, depending on the SMM, maximum recoverable strain reaches eight (8) to ten (10) percent. This shape memory phenomenon can be used to move or to stress other parts. During heating above (Af), the SMM can exert a strength. In such a way, strain recovery will be reduced, depending on the strength exerted. The more the strength is high, the more the strain recovery will be partial.

At a very high strength, the strain recovery will be null. If unstressed, the SMM will tend toward total recovery of its original shape. SMM also exhibits pseudo-elastic properties coming from its shape memory characteristics. Pseudo-elasticity results from the following phenomenon: when the SMM is at a temperature greater than (Af), it can be strained at a particularly high rate that is exhibiting unusual elasticity, arising from the shape memory properties of the material. Initially, when the SMM is stressed, the strain will increase linearly, as in an usual elastic material as seen in the graph below. However, at an amount of stress, called Sms, which is dependent on the particular SMM and temperature, the ratio of strain to stress is no longer linear since the strain increases at a higher rate as the stress increases at a lower rate. At a higher level of stress, the increase in strain will tend to become smaller. On the release or reduction of the stress, the reduction in strain will follow a different curve from the one manifested as the stress was increased, in the manner of a hysteresis loop as shown in the graph below.



Pseudo elastic property of Shape Memory Materials

Because of the pseudo elastic property of shape memory materials, the ferrule of the present invention can be manufactured in small dimensions, for example about 1 μm or less in diameter and 8 μm or less in length and can be deformed sufficiently to provide enough space to insert the fibers in the ferrule.

Accordingly, in Applicant's submission, the present application cannot be rendered obvious in view of D1 since reference D1 does not describe a ferrule made of a Shape Memory Material.

In the present application, an axial force is applied on the ferrule to deform it so that the fiber can be inserted so that the tool can be used. Whereas as stated on pages 4 and 5 of D1, in order to use the tool, the tool is inserted in an essentially rectangular shaped aperture and rotated in one direction so as to deflect the two sections comprising each spring clamp. At the end of the operation, the tool is rotated in the opposite direction and withdrawn from the aperture. Furthermore, as indicated by the Examiner, D1 does not even contemplate the use of slots. In the present invention, the longitudinal slots cut the ferrule from one extremity, traversing the length of the "centerer" or middle portion and stopping at a point between the "centerer" and the opposite extremity. Accordingly, the Applicant respectfully submits that the present application is not obvious in view of reference D1 on the grounds that D1 does not teach the subject matter of the present application and the skilled person in the art would not be easily and without difficulty led from D1 to the present invention.

The Examiner asserted that the subject matter of the present application differs from D1 by having slots, however the present application as not considered to be inventive in view of D2 which discloses a ferrule comprising slots to provide flexible characteristics to the device. Once again, the Applicant respectfully traverses the Examiner's rejection.

The projections (slots) of in D2 are additions of material provided on each end of the body of the described device and are uniformly distributed around the axis of the ferrule. Thus, the projections in D2 prevent the optical fibers from being crushed, even if the connection device has one of its ends bearing against a surface, whereas the slots in the present application serve a very different purpose.

Firstly, contrary to D2 in which the slots represent the addition of material, the slots of the present application represent the absence of material. The slots in the present application cut the diameter of the ferrule longitudinally. The slots as described in D2 do not cut the ferrule longitudinally. The slots of the present application operate to allow sufficient deformation of the bore to freely and reproducibly insert the optical fiber

into the bore. Each longitudinal slot cuts the ferrule from one extremity, traversing the length of the "centerer" and stopping at a point between the "centerer" and the opposite end. The function of the longitudinal slots is to ensure that the stress applied by the ferrule on the fiber when the bore is released is not too strong and as such avoids the risk that if one needs to put the ferrule in a narrow space, it becomes possible to radically bend the fiber without blocking it between the extremity of the ferrule and any other object limiting space in the direction of the longitudinal axis of the ferrule. The function of the projections (slots) in D2 is to protect the fiber outside of the ferrule. Whereas, the function of the slots in the present invention is to protect the fiber from the pressure exerted by the ferrule to maintain the fibers in position. Accordingly, in Applicant's submission, D1 in combination with D2 would not lead the skilled person to the subject matter of the present application.

The Examiner had also rejected claims 1 to 4 as obvious by combining D1 with US Patent 6,357,933 (hereinafter D5) and US Patent 5,768,455 (hereinafter D6). The Applicant respectfully traverses the Examiner's objection. In D5, the insert includes a slot 45 disposed at the support end and a slot 55 disposed at the receiving end. The purpose of slot 45 and 55 respectively is to allow the insert to compress the fiber when the insert portion is compressed on the support end. In our invention, the use of the slots serve a very different purpose, which is to allow easier enlargement of the ferrule bore. In D6, the slots (36) are used to fix a supplementary part on the assembly formed by the connector. Whereas, in our patent application, the slits are used to easily fix the fibers.

The Examiner had rejected claims 1 to 4 as obvious to the skilled person in the art in view of D1 in combination with EP 1 148 366 (hereinafter D3) and JP 2002 311293 (hereinafter D4). The Applicant respectfully traverses the Examiner's rejection.

D3 relates to a plug type connector that is adapted to be latched to a backplane wall in a fixed position and has a tapered front, noses or connector end for insertion into an adapter which plugs into the backplane wall. As stated on page 6, lines 29 to 35 of D3, a protective dust cap is insertable in the ferrule or connection end of the housing to protect the ferrule when the connector is assembled. Accordingly, the only purpose of the plug / cap of D3 is to prevent dust from entering into the bore of the fiber. The caps/pugs of the present invention have a wire that is attached to the center of the caps/plugs. The purpose of the plugs / caps of the present invention is to allow for optimal positioning of the optical fibers when the caps are removed and replaced by the optical fibers. The plug/cap of the present invention has a wire that is positioned at its center and is inserted inside the bore of the ferrule. When a fiber is to be inserted

into the bore of the ferrule, a first cap is removed and replaced with a first optical fiber. The first optical fiber will abut with the wire of the second cap, which ensures that the wire of the fist cap is aligned with the first optical fiber. The second cap is then removed and the second optical fiber is inserted into the bore of the ferrule and is abutted with the first optical fiber. Accordingly, in Applicant's submission, D1 in combination with D3 does not teach the subject matter of the present application.

The plugs / caps 35 and 46 as described in D4 function to place the fiber extremities at the middle of the ferrule length and to protect the fiber from dust, whereas, the function of the plugs / caps of the present invention is to permit optimal positioning of optical fibers into the ferrule such that the fibers are lined up.

Accordingly, the Applicant respectfully submits that the subject matter of the present application would not be obvious to the person skilled in the art in view of D1 in combination with either D2, D3, D4, D5 and D6 considering that none of these references alone or in combination would lead the skilled person in the art to the subject matter being described and claimed in the present application.

At this time, Applicant wishes to make certain amendments to the written description and the claims, as requisitioned and to better and more completely describe and claim the invention herein, all without the addition of new subject matter.

The Examiner had objected to claims 1 to 4 on the ground that they did not meet the requirements of Article 6 of the PCT. The Applicant has amended the claims for greater clarity and the Applicant respectfully submits that no new subject matter has been added to the claims.

In response to the Examiner's query with respect to the bore having a diameter that is slightly smaller that the diameter of the optical fiber, the Applicant respectfully submits that the bore is smaller than the optical fiber when there is no optical fiber inside the bore. This is one of the advantages of the present invention and benefits of having a ferrule made of a Shape Memory Material, which allows the fiber to be fixed by exerting pressure on said optical fiber. The ferrule will not crush the fibers as the bore diameter of the ferrule is not largely smaller that the fiber but only slightly smaller. Furthermore, the slots used limit the pressure that the ferrule exerts on the optical fibers.

The Applicant has also amended the description to ensure that all reference characters on the Figures are included in the description. All amendments made to the claims on file do not add subject matter to the present invention and are completely supported by the description as originally filed. The Applicant respectfully submits that

the amendments to the claims are solely for the purpose of clarity. Amended claim 1 corresponds to old claim 1. New claim 2 corresponds to old claim 1. New claim 3 corresponds to old claim 1. Support for new claim 4 can be found at page 8 of the description. New claims 5 and 6 are supported by the specification at pages 9 to 11. New claims 7 and 8 correspond to old claim 3 and are supported by the specification at pages 9 to 11. Amended claims 9 and 10 correspond to old claim 4.

The Examiner has objected to the description on the ground that it did not meet the requirements of Articles 5 and 11.13 (m) of the PCT.

The Applicant has amended the description of the application in order to more clearly explain the invention. The amendment made by the Applicant to the description at pages 1 to 12 do not add any new subject matter to the present invention but only serve to better explain the invention.

The Applicant encloses a black line version of the application indicating the changes made to the description and claims.

In response to the Examiner's objection to the reference to the document on page 1, line 15 and on page 3, line 1, the Applicant respectfully submits that the reference on page 1, line 15 is to a US patent application having publication number 2002/0037140 and entitled "Composite ferrule of connector for optical fibers, and Method of manufacturing same". With respect to the Examiner's objection to page 3, line 1, the Applicant has amended the description at page 3, line 1 to add the international publication number WO 2004/015473 for its international patent application entitled " A Connector for Optic Fibers ".

The Examiner had objected to the Figures presently on file on the ground that they did not meet Rule 11.13 (a) of the PCT. The Applicant has amended the Figures to clearly show all the parts of the inventions and to identify all the parts by references in the specification.

Please replace Figures 1 to 5 presently on file with renumbered Figures 1 to 9 submitted herewith.

Old Figure 1 corresponds present Figure 1.

New Figure 2 is similar to old Figure 1 and present Figure 1.

New Figure 3 is an expanded view of the Ferrule as shown in Figure 1.

New Figure 4 is an illustration of the tool, which was described on page 10 of the description as originally filed and was included on original Figures 2 to 5.

Renumbered Figure 5a and 5b, which corresponds to original Figure 2.

Renumbered Figure 6a and 6b, which corresponds to original Figure 3.

Renumbered Figure 7a and 7b, which corresponds to original Figure 4.

Renumbered Figures 8 and 9, which corresponds to original Figure 5.

The Applicant has removed the page number of the Abstract page.

Respectfully submitted,

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[MTL_LAW\914125\1]

Flexible Ferrule Device ~~FOR~~For Connection ~~OF~~Of Optical Fiber ~~AND~~And Use Thereof

BACKGROUND OF THE INVENTION

The present invention is directed to a connector assembly for connecting optical fibers for use in optical communication systems, and particularly to a flexible ferrule device for connecting optical fibers for such use. The present invention further relates to a method of connecting optical ~~fiber~~fibers using such a device and to a tool for use thereof.

The invention relates to an optical fiber connection device that allows for the end-to-end alignment of two optical fibers in a way such as to permit a light signal to pass from one fiber to the other fiber with minimal attenuation and reflection losses. This device also makes it possible to reduce any air layer between the ends of the two fibers in contact by maintaining pressure on their ends.

Ferrules and related technology are known in fiber optic connection. The art is replete with examples, including U.S. ~~Patent N°s~~Patents N° 6,579,615~~-B2~~; 6,533,469~~-B1~~; 6,416,236~~—B1~~; 6,357,933~~;~~ and U.S. Patent Application Publication N° ~~U.S. 2002/0037140.~~"2002/0037140 entitled "Composite Ferrule of Connector for Optical Fibers and Methods of Manufacturing same". A ferrule for use as a connector in an assembly with optical fibers requires high dimensional accuracy and precision, yet in an extremely small-diameter conduit for positioning and holding optical fiber. Present or proposed ferrule connectors for optical fibers, such as U.S. Patent ~~Number~~N° 6,357,933 to Lucent Technologies Inc. may not be amenable to ease of manufacture or assembly with optical fiber by the technical personnel carrying out the operation. Thus, in spite of the known application of ferrules in optical fiber connection, there is a continuing need for improvement in the technology of the design and use of ferrules for this purpose. For example, relating to aspects of attenuation and return loss, the establishing of as perfect as possible fiber-to-fiber contact between end portion of optical fibers and the prevention of face dust accumulation between the fiber faces. There is also a need to improve the ease of use of ferrules in an assembly for connection of optical fibers in an optical communication system, by the person carrying out the operation.

Optical fibers are generally made of glass or polymers and are made of successive and concentric layers. At the inner centre of the fiber, one can find the core of the fiber. The core is surrounded by the cladding. Both constitute the wave-guide that will conduct light. They are made of glass for better performance, and thus they are fragile.

The cladding is generally coated with a polymer layer that protects the glass from scratches and allows the optical fiber to bend, or to exert tensile strength on it. The last layer of protection is called the buffer.

For example, the diameter of the core can be between 6 to 60μm and the diameter of the cladding is generally 125 μm, but can be 50μm to 200μm. The buffer diameter is generally 250μm for fibers to be assembled in a cable with other optical fibers. If used alone, a fiber will receive a 900μm buffer made of different layers to protect glass and polymers from water and sunlight.

In the field of photonics, optical fibers are used for the transmission of optical signals as well as for the linking of optical switches, waveguide grating devices, optical amplifiers, ~~module~~modules and the like. Optical transmission systems relying on photonics have been taking on greater importance, as optical signals are capable of carrying a far larger quantity of information as compared to typical copper wire communication systems. For example, with the technology of Dense Wavelength Division Multiplexing (DWDM) and Demultiplexing it is possible to transmit multiple wavelengths in a single fiber, providing data capacities of 40 Gigabits per second and greater.

Optical networks which require DWDM equipment and other such devices demand multiple amounts of ~~splicers~~splices and connectors. Splicing and connecting play a significant role in network cost and performance. Although mechanical splicing of optical fibers may be sufficient where there is no requirement for frequent connection and disconnection, current technologies for connectors or for splicing are still time consuming and expensive, since they are difficult to miniaturize and to manipulate. As well, there will be circumstances where connectors will be used in applications where flexibility for routing or reconfiguration is necessary or for connection of an end use device, such a computer or other electronic ~~device~~devices to a fiber or to other such devices. Current technologies for connectors or for splicing are still time consuming and expensive, since they are difficult to ~~miniature~~miniaturize and to manipulate.

As poor connection between the ends of two optical fibers will lead to signal distortion and loss of strength, a number of approaches have been proposed for proper optical fiber connections which will provide a good signal conduction. One such approach is set out in our ~~U.S. Patent Nº 60/358,392 titled~~ "international patent application entitled "A Connector for Optic Fibers~~" PCT/CA03/01195.~~" and published as WO 2004/015473. This application is incorporated herein by reference in its entirety.

In our aforesaid application, we propose a connector for connecting the ends of two optical fibers by abutment, wherein the connector is divided into a plurality of fingers

that extend longitudinally at each end and a fiber conduit extending from the first end to the second end. Such a connector is manufactured from ~~shape memory material~~Shape Memory Material (SMM), such as ~~polymer ceramic~~polymers, ceramics, or a metal ~~alloy, with low elastic modulus.~~ alloys. In general, such materials when deformed at low temperature from a rest condition ~~by any suitable means, such as~~ by mechanical deformation ~~or temperature increase,~~ will then be biased to return to ~~a~~the rest condition when ~~the cause of deformation is removed.~~ one heats them up over a temperature specific to the material used.

Use of such an optical fiber connector as described above is however not totally satisfactory as during the step of cooling or release of stress ~~the connector to allow it to return to its rest condition~~, there may be a tendency for the connector to push the ends of the optical fibers apart slightly. This makes it necessary during the operation of connecting optical ~~fiber~~fibers ends to include an additional step of restraining the optical fibers in a fixed position during the step where the connector returns to its original size, to prevent the optic fibers from being moved apart on the ~~cooling~~heating of the connector. Accordingly, some form of fixed clamping is required, of the ~~sheath~~buffer that typically covers and protects an optical fiber or bundle of such fibers to prevent axial movement of the optic fibers being connected. Such a step is cumbersome to the easy and quick connection of optical fibers using an aforesaid connector, requiring a certain degree of operational skill on the part of the technician carrying out the operation.

~~Accordingly, although a SMA~~ Although a Shape Memory Material (SMM) connector, as described in our ~~U.S. Application N° 60/358,392~~international patent application published as WO 2004/015473, provides an improved means for connecting optical fibers, this still requires the use of certain operational skill by a technician carrying out the operation. As well, there is a need for improvement, such as in attenuation and return loss, fiber-to-fiber contact, ~~dirt~~dust accumulation and the like, in relation to optical fiber connection with ferrules, despite the common use of such technology in the field of optical signal transmission. Thus, there is a continuing need for an optical fiber connector assembly that is simple and quick to install and use and to maintain a good signal conduction between optical fibers, as well for a connection to be made and provided at a near end use device.

For purposes of the present application, with respect to ~~shape memory material~~Shape Memory Material (SMM), reference may be made to AFNOR Standard "Alliages à mémoire de ~~derme~~ Forme - Vocabulaire et Mesures" A 51080-1990, herein incorporated entirely by reference.

~~Materials, which are suitable for the present invention, will illustrate a very low Young's modulus (elastic modulus) and /or pseudo elastic effect. Pseudo elastic effect is encountered in SMM. Concerning the shape memory effect,~~ Shape Memory Materials (SMM) are characterized by the following behaviour: when the material is below a temperature (~~M_F~~Mf), which is a property dependent on the particular SMM, it is possible to strain (deform) the material ~~from about some tenths of a percent to more than about eight percent, depending on the particular SMM used~~. The strain is quite easily obtained by stressing the material with a relatively low stress. When stress is released, SMM retains the greatest part of the strain. When the SMM is heated above a second temperature (~~A_F~~Af), which is also dependent on the particular SMM ~~as well as the applied stress~~, the SMM will ~~tend to recover its assigned shape~~recover the strain. The recovery of strain is total unless the stress used to deform SMM exceeds the yield strength of the material. Thus, depending on the SMM, maximum recoverable strain reaches eight to ten percent. This shape memory phenomenon can be used to move or to stress other parts. During heating above (Af), the SMM can exert a strength. In such a way, strain recovery will be reduced, depending on the strength exerted. The higher the strength, the more the strain recovery will be partial.

At a very high strength, strain recovery will be null. If unstressed, the SMM will tend ~~toward~~towards total recovery of its original shape. ~~If a stress is maintained, the SMM will tend to particularly recover its original shape. Concerning the pseudo elastic effect,~~SMM also exhibits a pseudo-elastic properties coming from its shape memory characteristics. Pseudo elastic property is also referred to as super elastic effect.

The pseudo-elasticity results from the following phenomenon: when the SMM is at a temperature greater than ~~its~~ (~~A_F~~Af), it ~~may~~can be strained at particularly ~~higher~~high rates, that is exhibiting ~~non-used~~unusual elasticity, arising from the shape MEMORY properties. Initially, ~~in~~when the SMM ~~when~~is stressed the strain will increase linearly, as in ~~a used~~an usual elastic material.

However, at an amount of stress, called Sms, which is dependent on the particular SMM and temperature, the ratio of strain to stress is no longer linear, since strain increases at a higher rate as stress ~~is increasing~~increases at a lower rate. At a ~~particular~~ higher level of stress, the increase in strain will tend to become smaller. ~~This non-linear effect exhibited by SMM a temperature above (A_F) may manifest itself as a hysteresis like effect, wherein on~~On the release or reduction of stress, the ~~deduction~~reduction in strain will follow a different curve from the one ~~mahifest~~manifested as stress was increased, in the manner of a hysteresis like loop.

An example of such an above material would be a shape memory alloy (SMA). Examples concerning activation of the shape memory element in a SMA include D.E. *Muntges et al.*, "Proceedings of SPIE~~,~~", Volume 4327 (2001), pages 193-200 and *Byong-Ho Park et al.*, "Proceedings of SPIE~~,~~", Volume 4327 (2001), pages 79-87. Miniaturized components of SMA may be manufactured by laser radiation processing. See, for example, *H. Hafer Kamp et al.*, "Laser Zentrum ~~Hannover~~Hanover e.v.~~," Hannover~~", Hanover, Germany [publication]. All of the above references are incorporated herein by reference.

Materials, which are suitable for the present invention, will illustrate pseudo elastic effect. SMM technology is particularly suited to optical fiber connection, as it offers:

a) a high strain capability allowing a sufficient enlargement of the bore diameter to freely insert the optical fibers;

b) mechanical retention of fibers ; and

c) allows to create a strength of abutment between the faces of fibers.

The ~~connector~~ferrule may, for example, be made from a shape memory polymeric material, such as isostatic polybutene, shape memory ceramics such as ~~zirconium~~Zirconium with some additions of Cerium Beryllium or Molybdenum, ~~copper~~or shape memory alloys: Copper alloys including binary and ternary alloys, such as Copper-~~-Aluminum~~-Aluminium alloys, Copper~~-~~-Zinc alloys, Copper~~-Aluminum-~~-Aluminium-Beryllium alloys, Copper~~-Aluminum-~~-Aluminium-Zinc alloys and Copper~~-Aluminum-~~-Aluminium-Nickel alloys, Nickel alloys such as Nickel~~-~~-Titanium alloys and Nickel~~-~~-Titanium~~-~~-Cobalt alloys, Iron alloys such as Iron~~-manganese~~-Manganese alloys, Iron~~-~~-Manganese~~-~~-Silicon alloys, Iron~~-~~-Chromium~~-~~-Manganese alloys and Iron~~-~~-Chromium~~-~~-Silicon alloys, ~~Aluminum~~Aluminium alloys, and high elasticity composites which may optionally have shape memory metallic or polymeric reinforcement.

With respect to the present invention, two optical fibers must be prepared so that the buffer is retrieved on a sufficient length to allow the ferrule to keep the claddings and cores in front of each other. A cleaving tool will advantageously cleave the ends of the optical fibers such that the extremities are flat and nearly perpendicular.

To connect the ends of two optical fibers using ~~our~~the ferrule connector, the connector must be first deformed ~~in any suitable way, such as by the application of a compressive force along its longitudinal axis~~to enlarge the diameter of its bore, which in its rest position is slightly smaller than the optical fibers. One end of the optical fiber is inserted into the bore of the ferrule and then a second optical fiber is inserted into the other end of the bore of the ferrule until the fibers face one another. An optical gel may

also be applied, which ~~would be~~have substantially of the same index of refraction as the optical fibers to assure uniform optical properties across the connection between the fibers.

Once the optical fibers ends are fully inserted into the connector, and the respective ends abut, the force applied on the connector may then be released and the connector allowed to ~~return to an initial shape. On released~~shrink on the inserted fibers. Upon release of the force on the connector, the connector will then tend to exert a controlled compressive force on the optical fibers, sufficiently strong ~~enough~~ to retain the ~~optic~~optical fibers in an abutment position but small enough not to damage the optical fibers by compression~~.SMA technology is particularly suited to optical fiber connection, as it offers mechanical retention of fiber and can create an abatement between and faces of fibers~~.

SUMMARY OF THE INVENTION

The device for connecting optical fiber comprises a ferrule and end caps with wire ~~centers~~centres of which the extremities are located at ~~the centerer~~middle of the ferrule length; said ferrule comprising a bore that traverses the central axis of the ferrule, a middle portion or "centerer", connecting clamp means at the free ends of the ferrule, linked together by the "centerer"; the ferrule being made of any material that has the property of ~~shape memory,~~Shape Memory Material (SMM) and deformation equipment allowing for its implementation.

Unless otherwise indicated herein, in the present document "device" refers to the device that connects optical fibers.

BRIEF DESCRIPTION OF THE FIGURES

Reference will now be made by way of example to the accompanied figures, showing articles made according to the preferred embodiments of the present invention.

Figure 1 is a perspective view of the ferrule in accordance with the present invention~~;~~.

Figure 2 is a perspective view of a second realisation of a ferrule in accordance with the present invention.

Figure 3 Is a perspective view of the ferrule and its plugs in accordance with the present invention.

Figure 4 is a perspective view of the tool in accordance with the present invention.

Figure 5 is a perspective view of the tool showing the opening of the "centerer" on the ferrule.

Figure ~~3~~ 6 illustrates the placement of the first fiber.

Figure ~~4~~ 7 illustrates the placement of the second fiber.

Figure ~~5~~ 8 illustrates the removal of the tool.

Figure 9 illustrates the strengths exerted by the ferrule on the two connected optical fibers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described more fully hereafter with reference to the accompanying drawings in which preferred embodiments are shown.

A. Device embodiment:

The device for connecting optical fibers comprises a ferrule and may be made from any suitable material such as either a polymer based material, metallic alloy or ceramic or any material that has ~~a low Young's modulus such as polymeric materials or Cu_2Be elastic alloys or any material that has~~ the property of pseudo elasticity for its implementation, thus, it must be a Shape Memory Material (SMM). The ~~shape memory material~~Shape Memory Material may be any as described above, with desired properties. ~~The shape memory material may be~~ The Shape Memory Material may be a ceramic, a polymeric or a metallic alloy such as copper based or iron based alloy, or it can be a nickel / titanium alloy. The composition of the ~~shape memory material~~Shape Memory Material (SMM) may be more complex and include other elements in variable quantities.

~~The shape memory material~~ The Shape Memory Material (SMM) is advantageously ~~used in its austenitic phase~~at an application temperature > Af for the realization of an optical-fiber connecting ferrule. In effect, in this phase, it has deformation capabilities, referred-to as pseudo-elastic, which are more important than the elastic-deformation ~~capabilities~~capacities of a metallic or ceramic alloy that does not have the properties of ~~shape memory~~ pseudo-elasticity.

The ferrule is generally cylindrical and, before its first connection to optical fiber, it is characterized by the elements described in Figure 1, namely: **a bore** (1) that traverses the central axis of the ferrule, from one end to the other end; with respect to the present invention, this bore (1) has the very specific characteristic in that it must be slightly

smaller in diameter than the cladding diameter of the optical fibers to be connected; a **middle portion** (2), commonly referred to as "centerer"~~, at a level wherein the diameter of the bore of the ferrule is slightly smaller than the diameter of the optical fibers that it is to connect.~~ and **connecting clamps** (3).With respect to the present invention, this "centerer" (2) has the function (a) to centre, ~~the two optical fibers with just sufficient radial distortion allowed to ensure that the two fiber~~without any radial distortions, the ends of the two optical fibers from which the buffer as been retrieved on the desired length. Centering of the un-buffered glass fibers ensures that the two fibers cores are face to face with the minimum of misalignment in order to obtain an optimal optical signal transmission; ~~(b) to firmly maintain each of the two optical fibers in place so they cannot separate from one another; (c)~~and (b) and to maintain the two optical fibers in contact with each other with an axial strength predisposition in order to ensure minimal attenuation and reflections at their junction, particularly, in order to counter the effects of a thermal expansion of the ferrule or traction on the optical fibers. This maintenance is advantageously obtained by an axial extension of the "centerer" (2) ferrule's with the aid of a tool, as described later. After the "centerer" (2) is relaxed, it tends to naturally contract, maintaining the two fibers in contact and under pressure on each other.

At each end of the ferrule, ~~**connecting clamps (3) that**~~**the connecting clamps** (3) are linked together by the "centerer" (2). Each of the connecting clamps ~~is~~(3) resting in a closed state making the diameter of the ferrule's bore smaller than the diameter of the optical fibers to be connected. With respect to the present invention, the connecting clamps (3) are designed to be independently opened by a tool, as hereinafter described, so that one can introduce un-buffered fibers to the "centerer" (2), alternatively from one side, and then the other side of the ferrule. When tool releases the connecting clamps, it closes on the cladding of the fiber to maintain the fiber firmly in position.

~~Clamps may be prolongated by a section comprising a central bore with a diameter a little bit smaller that cladding diameter.~~

~~Thus, the clamps will restrain the cladded part of the fiber to avoid breaking or failure at the junction between cladded and uncladded fiber~~

~~A free length of uncladded fiber allows to adapt to concentricity default between outer diameter of cladding and uncladded fiber.~~

With respect to the present invention the connecting clamps (3) have the function of firmly holding each of the two fibers in the ferrule in a way such that the contraction of

the "centerer" (2), once released by the tool, allows for the compression of one fiber against the other.

When both connection clamps (3) have been released, they firmly maintain the two optical fibers to be connected. Then the tool will release the "centerer" so that it centres the two fibers, and it contracts to press optical fibers on each other.

As shown in figure 2: each connecting clamp may be prolonged by a portion: buffer fixers (7) comprising a central bore (8) with a diameter a slightly smaller than the diameter of the buffer of the fiber.

Thus, the buffer fixers (7) will restrain the buffered part of the fiber to avoid breaking or failure at the junction between buffered and unbuffered fibers.

Junction between fiber bore (1) and buffer bore (8) will advantageously be done by a conical portion (9).

In a preferred embodiment, end cones (4) are located at the ~~extremites~~extremities of the ferrule to allow ~~for the deformation of the ferrule in advance of~~the opening of each clamp and to easily allow for the smooth insertion of the optical fibers. In a preferred embodiment, conic grooves (5) are located on each side of the "centerer" (2) to facilitate its expansion by the tool. ~~The connecting clamps have one or~~

With respect to the present invention, the ferrule has one of more pairs of longitudinal slots (6) that cut the diameter of the ferrule, traversing radially outward from the centre. Each slot (6) cuts the ferrule from one extremity, traversing the length of the "centerer" and stopping at a point between the ~~centre~~centerer and the opposite extremity. Figure 1 and 2 shows an example realisation with four longitudinal slots (6), comprising ~~two sets~~one set of two slots ~~at 90º. Each set comprises~~(6) at 90° to the other set of slots (6). One set of the two slots ~~cutting~~(6) cut the ferrule ~~radially outward in opposite direction and the two slots cut the ferrule along the orthogonal axis~~longitudinally outward from the opposite end of the other set of slots (6), to allow a better opening of the "centerer" (2) and of the two connection clamps (3). This illustration is not restrictive in terms of the number of slots (6). Cuts B to F visually illustrate the location of the slots (6) along the length of the ferrule. With respect to the present invention, these slots (6) operate to allow for sufficient deformation of the bore ~~of the centre~~(1) to ~~easily~~freely and reproducibly insert the optical fiber while ~~maintaining a reproducible bore that can be made using~~ conventional industrial means ~~and is minimally smaller than that of the optical fiber. In the case where a single slot is used, it could traverse the entire length of the ferrule~~are used to make the bore (1).

~~The~~ With respect to the present invention, the bore (1) of the ferrule is protected by two ~~caps~~cap wires (~~7~~10), as shown in Figure ~~2~~,3, in order to prevent contamination by dust or

any other ~~any~~ substances. These two ~~caps~~cap wires (10) have wire centres whose extremities ~~are located at~~touch one another in the middle of the "centerer" of the ferrule, to allow for optimal ~~centring~~positioning of optical fibers when replaced by them.

B. **Use of the ferrule~~:~~**

The ferrule will be used with a tool shown in Figure 4 that can deform it in order to put the optical fibers in place.

Only the basic functions for operation when used with the tool are described. The figures are presented only as an example and are not intended to limit the scope of possible implementation of the tool. For example, grip pliers, automated and motorized tools, tools built in and around each ferrule as a part of the connector, etc.

In one embodiment, this tool ~~essentially~~ comprises:

- A pair of external grips (12), each of the said external grips comprises a cone (13) that engage in the end cones (4) of the ferrule ~~at the two end cones~~.
- A pair of internal grips (14) that ~~engage~~engages in the conic grooves (5) of the "centerer" ~~of the ferrule.~~ (2) of the ferrule. Each of external grips (12) and internal grips (14) comprises a passage (16) that allows the tool to fit the ferrule and its end caps (10) on the tool. For example, this passage can be a circular hole or a side passage as shown on the figure 4.

a) **Deformation of the "centerer": Figure 5**

As ~~illustrated, the ferrule in this embodiment is "dumbbell" shaped, the diameter of the connecting clamps greater than that of the centerer. The~~shown in Figure 5a, the ferrule is placed on the two cones (15) (shown on Figure 4) of the internal grips (~~8), which are engaged one from the other. Each of the internal grips comprises a cone (9) that~~14). The two cones (15) engages each of the conic grooves (5) of the ferrule's "centerer" (~~see Figure 2). Tension~~2). As shown in Figure 5b, tension is applied between the two ~~grips~~internal grips (14) to deform the "centerer" (2). This deformation can be broken down into two ~~phases~~components: one consisting of the elongation of the "centerer" (18) and another one consisting of the elongation of the bore's diameter (19) making it larger than the diameter of the fibers to be connected.

Usually, when one elongates a cylindrical part, the diameter of this part will shrink. Shape Memory Materials have the same behaviour.

The slots (6) that divide the "centerer" (2) allow the advantageous combination of the expansion of the "centerer" (2) with an increase in diameter of the bore (1) through the reaction obtained by the two conic grooves (5) of the "centerer" (2).

In this way, the slot or slots (6) in the "centerer" (2) allow for the enlargement of the bore's (1) diameter combined with the expansion of the "centerer" (2).

b) **Placement of the first fiber: Figure 6**

~~The two external grips (10) also comprise a cone (11) that is inserted in the entry of the connection clamps. The first external grip is brought close to the ferrule and its cone is inserted in the end cone. A force~~Elongation (18) of the "centerer" (2) and deformation (19) of the bore (1) are maintained. The cone (13) on the tool of a first external grip (12) is inserted in an end cone (4) of the ferrule. A force (20a) is applied between the external grip (12) and the corresponding internal grip (14) on the same side of the ferrule (see Figure ~~3~~6a). This force opens the connecting clamp (3) by using the force obtained from the end ~~cones~~cone (4) and conic groove (5). The opening of the connecting clamp (3) is such that the bore (1) diameter ~~is~~becomes larger than the diameter of the optical fibers.

Once the first connecting clamp (3) is opened, the cap wire (10) is removed and replaced with the first optical fiber, as shown in Figure 8b, which had been previously prepared. The fiber is abutted against the end of the second cap wire (10), which is still in place. In this way, the junction between the fibers ~~is~~will be made at the middle of the ferrule~~ ensuring the holding of the two fibers in place~~. Preparation of the ~~fiber~~fibers comprises removal of the ~~fiber, cladding~~buffer and cleaving the fiber. The first external grip (12) is then relaxed so that the first connecting clamp (3) closes on the fiber and maintains it in place (see Figure ~~3).~~ 6c with strength (22).

c) **Placement of the second fiber: Figure 7**

Strength (18) and deformation (19) of the bore (1) are still maintained.

The second external grip (12) is brought close to the ~~heading to the~~ ferrule and its cone (13) is engaged with the end cone (4) located on the ferrule. A force (20b) is applied between the external grip (12) and the corresponding internal grip (14) on the same side of the ferrule (see Figure ~~4~~7a). This force opens a second connecting clamp (3), as represented by arrows (23). The opening of the connecting clamp (3) is such that the bore (1) diameter is larger than the diameter of the optical fibers. After opening the second connecting clamp (3), the cap (10) is removed and replaced with the second optical fiber, which had been previously prepared.

The second fiber is abutted against the end of the first fiber, which is already in place (see Figure ~~4~~7a). The second external grip (12) is then relaxed so that the

second connecting clamp (3) closes on the fiber and maintains it in place (see Figure 47b with strength (24).

d) **Closing of the ~~*Ferrule:*~~ferrule: Figure 8**

The strengths (22) and (23) are maintaining the two fibers abutted.

~~Although the "centerer" of the ferrule is still maintained in traction, the relaxation of both external grips results in a contraction in the diameter~~Then the relaxation of both internal grips (14) will suppress the "centerer" (2) elongation (18) and result in a suppression of the deformation (19) of the bore in the region of the "centerer" (~~see Figure 5~~2). Thus, the "centerer" (2) is applying a radial force (25) on the two fibers leaving no "play" between the fibers and the ferrule. The two optical fibers are therefore perfectly ~~centered~~centred with respect to each other.

~~Once the force applied, the internal grip~~As strength (18) is relaxed, ~~and the~~ "centerer" (2) is no longer maintained in traction, its length tends to contract and ~~its~~the two fibers are abutted with strength (26) on each other. This compression allows for the contact of the two fiber ends to be maintained even under the effect of ~~traction of~~tensile strength exerted on one of the two fibers or the effective ~~thermo~~thermal expansion of the ferrule. ~~In the case of a drop in temperature, the ferrule will have a dimensional contraction greater than that of the fiber. This contraction would have a principal effect of increasing the contact pressure between the fibers and the pressure of the grips on the fibers. This increase in pressure will be tempered by using the materials listed in paragraph A and will have no effect on the junction of the fibers and their quality of transmission and reflection.~~

~~This remains true as long as the temperature of the ferrule remains higher than that of (M's). If the temperature of the ferrule is less than that of (M's), then the grips are relaxed and the fibers could slide within the ferrule with minimal effort and there is a reduction in contact pressure between the fibers. Thus, this case, there is a risk of degradation of transmission and reflection characteristics of the junction by separation of the fibers.~~ The tool may then be left in place if it is integrated with the ferrule, or ~~if~~ it is removed from the connection (see Figure ~~5)~~ 8) by passages (16).

A ferrule comprising buffer fixers (7) as represented in figure 4 will be used exactly in the same way as the description of portion B – use of the ferrule. The

connecting clamps (3) will exert strength on the fiber cladding and also on the fiber buffer.

This will reinforce optical fiber junction in the case of risks that fibers will be bent or submitted to tensile strength.

C. ~~C.~~ Reuse of the ferrule:

The ferrule of the present invention may be removable. In order to ~~do this, one may use~~remove the fibers, the same deforming tool used to create the junction can be used. In a particular embodiment, using the two internal grips (14) and cones (15), the "centerer" (2) is "bent" to relax the contact pressure between the two fibers and to open the bore (1). Then, using ~~the~~a first external grip~~,~~ (12) and its cone (13), the bore (1) is expended at the level of the first connecting clamp ~~is expanded to open the bore, thus~~(3). Thus making it possible to remove the first fiber. ~~The~~

A first cap (10) is then reinserted into the bore (10), allowing it to abut with ~~their~~the second fiber. The ~~same~~first external grip (12) is released to fix the cap (10) into the ferrule. A similar operation is repeated to the second external grip (12) and its cone (13) in order to expand the bore (1) at the level of the second connecting clamp, ~~which expands the bore,~~ thus making it possible to remove the second optical fiber and then the second cap (10) is inserted. The second connecting clamp (3) and the two internal grips (14) are then relaxed, and the ferrule may then be reused to make another optical junction or connection.

It is to be understood that the various features of the present invention might be incorporated into other types of ferrule devices, and that other modifications or adaptations might occur to workers in the art and it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. All such variations and modifications are intended to be included herein as being within the scope of the present invention as set forth. Further, in the claims herein, the corresponding structures, materials, arts and equivalents of all means or step-plus-function elements are intended to include any structure, material, or acts for performing the functions in combination with other elements as specifically claimed.

~~WE CLAIM:~~

We Claim :

1. A device for connecting optical fibers for the purpose of transmission of an optical signal comprising a ferrule, said ferrule comprising:

a) ~~1. A device for connecting optical fibers for the purpose of transmission of an optical signal comprising a ferrule, said ferrule comprising~~ a longitudinal extending body made of Shape Memory Material (SMM), said body having a middle ~~section and a first connection clamp and a second connection clamp with a conic end at each of its free ends~~portion, said middle portion having a first end and a second end, a first connection clamp and a second connection clamp, said connection clamps are located on either ~~side~~end of said middle portion, each connection clamp having a free end associated therewith, said body and said connection clamps also having a bore that traverses ~~its~~a central axis through said connection clamps and said middle portion, and said bore having a diameter ~~that is~~ slightly smaller than the diameter of the optical fibers to be connected~~, said middle portion having a first end and a second end body with conic sections with opposite angles at its first end and the second end, said connection clamps also having one or more longitudinal slots that cut the ferrule along the orthogonal axis, traversing radially outward in opposite direction and extending the length of the ferrule from one side to the other side, a first plug and a second plug and having a wire center that is inserted into the conic ends located at the free ends of the first connection clamp and the second connection clamp and extend until the center of the middle portion of the ferrule.~~

b) said body also having one of more pairs of longitudinal slots that traverse the diameter of said body, each of said pair of slots beginning within a connection clamp and extending to the free end of the other connection clamp, and wherein if there is more than one pair of slots not all pair of slots commence at the same connection clamp; and

c) a first cap and a second cap comprising of a wire whose diameter is approximately the same as the diameter of the optical fiber, said cap wires are inserted into the said bore of the said body, and said cap wires are

penetrating into the ferrule from each side, and said cap wires are abutted on each other at the middle of the length of the body of the ferrule.

2. ~~A tool comprising two interior grips that engage with the complementary sections of the conic sections on the middle portion of the ferrule of claim 1 and two exterior grips that engage with the ferrule at the conic ends located at the free end of the connecting clamps.~~The device of claim 1, wherein each of said connection clamps have at its free end a conic end penetrating along the axis of said connection clamp.

3. The~~ use of the device of claim 1, for connection optical fibers comprising:~~ device of claim 1, wherein said middle portion has conic grooves forming a ring around the junction between the first and second connection clamp and the middle portion, said conic grooves penetrating inside the first and second connection clamps.

~~(a) engaging the two interior grips on the tool of claim 2 with the complementary conic sections located at the ends of the middle portion of the ferrule to cause expansion of the length~~

4. The device of claim 1 wherein said pairs of slots form an angle which value is between 25° and 90°.

5. A tool for deforming a device for connecting optical fibers comprising:

a) two internal grips that engage with the ends on the middle portion of the ferrule of claim 1;

b) two external grips that engage with the free end of the connecting clamps of the ferrule; and

c) said internal and said external grips being traversed by a passage that allows optical fibers and cap wires to be removed from the ferrule or inserted in said ferrule.

6. A tool for deforming a device for connecting optical fibers comprising:

a) two internal grips shaped in a conical point that engage with the complementary sections of the conic grooves on the middle portion of the ferrule of claim 3;

b) two exterior grips that engage with the conic ends located at the free end of the connecting clamps of the ferrule of claim 2;

c) said conical point of the said internal grip and said external grips being traversed by a passage that allows optical fibers and cap wires to be removed from the ferrule or inserted in said ferrule.

7. The use of device of claim 1 combination with the tool of claim 5, for connection of optical fibers comprising:

a) engaging the two internal grips on the tool with the ends of the middle portion of the ferrule causing the slots and the diameter of the bore to expand~~;~~

~~(b) engaging the two exterior grips of the tool with the conic ends on the connection clamps which applies a compression force between the exterior grips and the connection clamps to increase the diameter of the bore;~~

~~(c) removing the first plug from~~ at said middle portion;

b) engaging a first external grip of the tool with the first connection clamp of ferrule, which causes the diameter of the bore in the first connection clamp to increase.

c) removing the first cap wire from the first connection clamp and inserting a first optical ~~fiber~~ into the bore until it is abutted against the second ~~plug connected to the second connection clamp and the first external grip is relaxed so that the connection clamp closes on the fiber and maintains it in place; and~~

~~(d) removing the second plug~~cap wire, said second end being maintained in position by the second connection clamp;

d) removing the first external grip so that the first connection clamp on the ferrule closes on the first fiber and maintains it in place;

e) engaging the second external grip of the tool with the second connection clamp of ferrule, which causes the diameter of the bore in the second connection clamp to increase;

f) removing the second cap wire from the second connection clamp and inserting a second optical fiber into the bore~~-and which~~, and said second optical fiber is abutted against the first optical fiber~~-and maintains it in place and the second external grip is relaxed so that the connection clamp closes on the fiber and maintains it in place.~~

~~(e) release of the center, causing diameter and length decrease, whereby sufficient force is applied by the device to center the fibers and abut the fiber end faces for light signal transmission.~~

~~4. The use of claim 3 wherein the tool may be used;~~

g) removing the second external grip from the second connection clamp of ferrule so that the second connection clamp of the ferule close on the second optical fiber and maintains it in place; and

h) removing the two internal grips from the ends of the middle portion of ferrule, causing the middle portion of the bore to shrink on the optical fibers to centre them in front of each other for light transmission, and at the same time causing that length of the middle portion of ferrule to decrease, said length decrease creating sufficient force to firmly abut the fibers end on each other for light transmission.

8. The use of device of claim 1 combination with the tool of claim 6, for connection of optical fibers comprising:

a) engaging the two internal grips on the tool with the complementary conic grooves located at the ends of the middle portion of the ferrule causing the slots and the diameter of the bore to expand at said middle portion;

b) engaging a first external grip of the tool with the conic end on the first connection clamp of ferrule, which causes the diameter of the bore in the first connection clamp to increase.

c) removing the first cap wire from the first connection clamp and inserting a first optical fiber into the bore until it is abutted against the second cap wire, said second end being maintained in position by the second connection clamp;

d) removing the first external grip so that the first connection clamp on the ferrule closes on the first fiber and maintains it in place;

e) engaging the second exterior grip of the tool with the conic end on the second connection clamp of ferrule, which causes the diameter of the bore in the second connection clamp to increase;

f) removing the second cap from the second connection clamp and inserting a second optical fiber into the bore, and said second optical fiber is abutted against the first optical fiber;

g) removing the second external grip from the conical extremity of the second connection clamp of ferrule so that the second connection clamp of the ferule close on the second optical fiber and maintains it in place; and

h) removing the two internal grips from the two conical grooves of the middle portion of ferrule, causing the middle portion of the bore to shrink on the optical fibers to centre them in front of each other for light transmission, and at the same time causing that length of the middle portion of ferrule to decrease, said length decrease creating sufficient force to firmly abut the fibers end on each other for light transmission.

9. The use of device of claim 1 and the tool of claim 5 to remove the fibers for reuse of the connecting device for optical connection of optical fibers.

10. The use of device of claims 2 and 3 and the tool of claim 6 to remove the fibers for reuse of the connection device for optical connection of optical fibers.

Abstract

The present invention is directed to a connector assembly for connecting optical fibers ~~for use~~ in optical communication systems, and particularly to ~~a~~ flexible ferrule device for connecting optical fibers for such use. The present invention further relates to a method of connecting optical fiber using such device and to a tool for the use thereof.

The invention relates to an optical fiber connection device that allows for the end- to- end alignment of two optical fibers in a way such as to permit a light signal to pass from one fiber to the other fiber with minimal attenuation and reflection losses. This device also makes it possible to reduce any air layer between the ends of the two fibers in contact by maintaining pressure on their ends.

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